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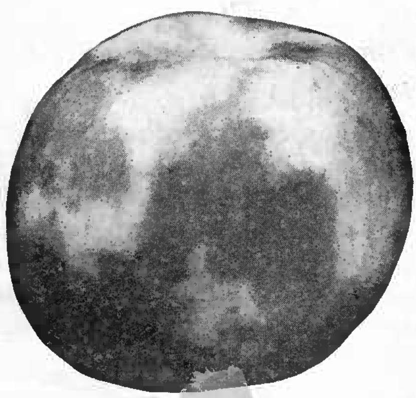
DISEASES of APPLES IN STORAGE



STORAGE DISEASES take a heavy annual toll on the harvested crop of apples, greatly reducing an important food supply and increasing the cost and uncertainty of market operations.

The responsibility for this loss may lie with the orchardist, the transportation company, the dealer, or the storage management.

Delay in warm packing sheds or cars shortens the natural life of apples and greatly increases their tendency to rots and scald. Filling the storage rooms so rapidly that cold-storage temperatures can not be maintained has a similar bad effect.

Apple rots are slow to start at a temperature of 32° F., but if a beginning has been made at a higher temperature they can proceed much more rapidly.

In cases of unavoidable delay in cooling, the losses from scald can be greatly reduced by good ventilation. Apples scald far less when in boxes, baskets, or ventilated barrels than in the usual tight barrel. Green fruit is much more susceptible to scald than that which is well matured. Wrapping apples in oiled wrappers or packing them in shredded oiled paper furnishes the most complete protection against scald.

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DISEASES OF APPLES IN STORAGE

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CONTENTS

PRINCIPLES GOVERNING DISEASE CONTROL

THE diseases that appear on apples in storage and upon their removal may be the result of storage conditions, or their occurrence may have been predetermined by orchard and transportation conditions. They may be due to the work of a parasite or to the direct action of unfavorable conditions upon the fruit itself. Diseases like scab and certain rots that are definitely traceable to the action of particular fungi are called parasitic diseases, while bitter pit, water core, and scald are known to be due wholly to abnormal physiological conditions in the fruit itself and are called nonparasitic or physiological diseases. Both parasitic and nonparasitic diseases can be prevented largely by proper methods of growing and handling the fruit, but each disease has its own peculiar laws of behavior upon which the requirements for its control must be based.

SCAB

Scab [1] is a parasitic disease and mainly an orchard disease. It can be largely controlled by carrying out the spraying schedules that have been developed and recommended for the different fruit sections. It is particularly serious in the orchards of the northeastern United States and in those of the humid sections of the Pacific Northwest, but it also occurs at the higher altitudes as far south as Virginia, North Carolina, and Arkansas.

Scab may appear on the picked fruit as large corky or dark sooty spots with a light-gray margin, or as small sooty spots or specks often irregular in outline and usually without the gray margin.

[1] *Venturia inaequalis* (Cke.) Wint.

(Fig. 1.) The latter form of the disease is the one that is most likely to pass into storage packages. With both the large and the small spots the protecting skin is broken and the apple exposed to early destruction by the rot organisms. Pink rot and blue mold are among the most common decays that follow scab.

Scab sometimes continues to develop in storage, but the characteristics of the spots are quite different from those found at picking time. They are smooth, black, and sunken, sometimes attaining a diameter of one-fourth of an inch before the fungus breaks through to the surface or causes any roughening of the skin. The development of the scab fungus is checked by low temperatures, and scab ordinarily makes little trouble in cold storage except as a source of rot infections; yet a late spread of the disease in the orchard is sometimes followed by a serious development in storage.

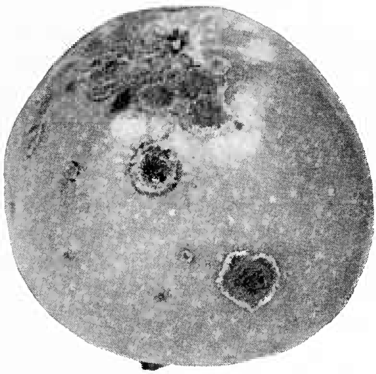

FIGURE 1.—Scab as it appears at picking time on a White Pearmain apple

BLOTCH

Blotch[2] is a parasitic orchard disease. It can be controlled by orchard sanitation and properly timed spray applications. It is a serious disease only in the more southern orchards of the Eastern and Middle States, but it seems to be gradually spreading northward.

Blotch appears on the fruit as hard brown or black blotches with jagged margins. The cuticle does not peel off, as with scab, but the protecting skin layers are killed and often broken by fissures and cracks. (Fig. 2.) Badly blotched apples are usually discarded or sold for immediate use, but those with a few small spots sometimes get into storage. The disease makes little if any development at cold-storage temperature, but the blotch spots may furnish a starting point for storage rots, particularly black rot and Alternaria rot.

FIGURE 2.—Blotch on a Ben Davis apple

FRUIT SPOT

Fruit spot[3] is a parasitic disease that can be controlled by midsummer spraying, yet is often found in abundance on the harvested fruit. It is of common occurrence in the orchards of the Atlantic coast from Maine to North Carolina, and it also occurs in Ohio, Missouri, and Arkansas. It has also been described under the names fruit speck, New Hampshire fruit spot, and flecked spot, and is sometimes referred to as Brooks spot and included in the term Baldwin spot.

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[2] *Phyllosticta solitaria* E. and E.

[3] *Mycosphaerella pomi* Passer.

The spots are small, seldom having a diameter of more than three-sixteenths of an inch. They are more highly colored than the normal skin, taking a deep red when on the red or blush areas and a dark green when on the green or yellow fruit surfaces. The center of the spot is usually specked or flecked with black, giving an appearance that does not occur in any other spot disease. (Fig. 3.) This flecked appearance is seen to better advantage after a very thin peel has been removed from the apple. The spots are shallow, usually affecting only the skin tissue. They may be slightly sunken, but usually at picking time have little or no corky tissue.

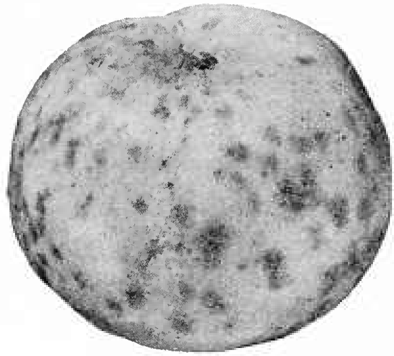

FIGURE 3.—Fruit spot on a Grimes Golden apple

In common storage the fruit spots may become more sunken and develop a shallow layer of corky tissue beneath, and the inconspicuous ones may develop so that the spots appear more numerous. If the fruit is delayed in reaching storage similar changes may occur, but when the apples are placed in cold storage immediately development is extremely slow. With fruit spot the protecting skin layer is not destroyed, and, unlike scab and blotch, the disease does not serve as a source of rot infection.

JONATHAN SPOT

FIGURE 4.—Jonathan spot on a Jonathan apple

Jonathan spot is a nonparasitic disease and can not be controlled by spraying. It is apparently associated with a varietal weakness in the epidermal tissue of the apple. It is particularly common on Jonathan apples, but it occurs on the Stayman Winesap, Esopus Spitzenberg, Wealthy, Rome Beauty, and a number of other varieties. The disease varies with the season, but is found in all sections where susceptible varieties are grown.

Jonathan spot appears as small black or brown spots that give the apple a somewhat freckled appearance. (Fig. 4.) In the earlier and more typical stages of the disease the spots are very superficial, usually being entirely removed by the thinnest possible peel; later they may become somewhat enlarged and develop a shallow layer of corky tissue immediately beneath. Jonathan spots differ from those of either fruit spot or bitter pit in being smaller and more superficial and in having a solid brown color and a clear-cut margin.

Jonathan spot may occasionally appear on the fruit before it is picked, but the main development of the disease is after removal from the tree. In general, the highly colored apples are more likely to be affected than the greener ones, but in storage the greener apples sometimes develop a large number of spots that closely resemble a speckled scald. Large apples usually are more susceptible to the disease than smaller ones. The disease is greatly decreased by low temperatures. (Fig. 5.) Fruit held in common storage has been found badly affected with Jonathan spot at the end of 2 weeks, while similar fruit placed immediately in cold storage has been entirely free from the disease at the end of 8 weeks and practically free at the end of 14 weeks. Apples that have a tendency to Jonathan spot sometimes develop the disease very rapidly upon removal from storage. The most effective means of control is found in hastening the fruit to cold storage and in keeping it as cool as possible after removal. Jonathan spots furnish a point of infection for Alternaria and other rot organisms.

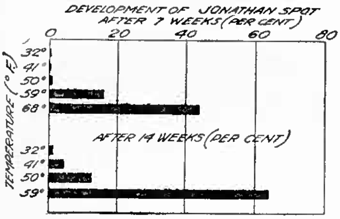

FIGURE 5.—Effect of temperature on the development of Jonathan spot on apples. The upper part of the figure shows the percentage of Jonathan spot developed at the different temperatures at the end of 7 weeks; the lower part shows the percentage developed at the end of 14 weeks. At 68° F. the apples had rotted before the second record was taken

BITTER PIT

Bitter pit is a nonparasitic disease, apparently due to derangements in soil-moisture conditions. It occurs on apples in all sections of the United States and is a serious disease in Europe, South Africa, and Australia.

Bitter pit has also been described under the names Stippen, Baldwin spot, and fruit pit. In the United States the Baldwin, Grimes Golden, Northern Spy, and Rhode Island Greening varieties are particularly susceptible to the disease.

The disease is characterized by the development of small brown spots or streaks in the flesh of the apple, most abundant just beneath the skin. (Fig. 6.) The spots are associated with the water-conducting strands and sometimes follow this tissue deep into the flesh. The disease is usually evident on the

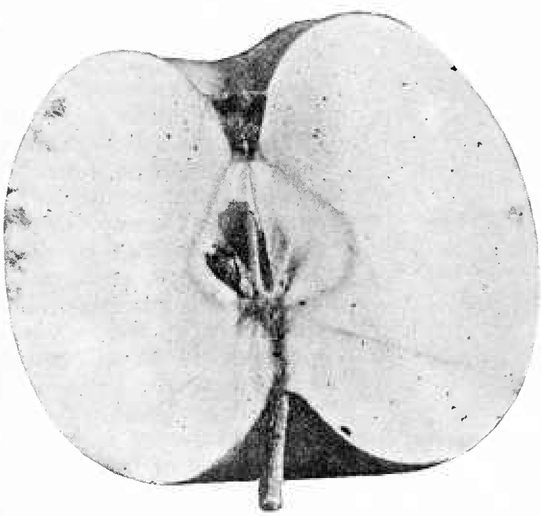

FIGURE 6.—Bitter pit on a Grimes Golden apple as seen in cross section

surface of the apple as sunken, bruiselike spots that somewhat resemble hail injury. At first these spots have a water-soaked appearance, but later they may become more highly colored than the surrounding skin, taking a deep red when on a blush area and retaining a bright green when on a green or yellow fruit surface. They finally become a deep brown and are much sunken, giving the apple a badly pitted appearance. Bitter pit is confined almost entirely to the blossom half of the apple. It differs from Jonathan spot and fruit spot in this respect, and also in the fact that the spots are bruiselike, more sunken, contain more dead brown tissue, and are more deeply seated. Jonathan spots and fruit spots are usually entirely removed in peeling an apple, but the bitter-pit spots are cut into and made more evident.

Bitter pit is largely due to some overstimulation of the fruit during the latter part of the growing season. Heavy irrigation and heavy rainfall during the last weeks before picking are particularly favorable to the disease. (Fig. 7.) Cultivation, fertilizers, cover crops, pruning, thinning the fruit, and the age of the trees may all have a bearing on its occurrence. Everything that contributes to the stabilizing of the moisture conditions in the soil and to an even, normal growth of the fruit throughout the summer is of value in the prevention of the disease. Bitter pit is worse on the fruit from young trees than on that from old ones. In general, it is worse on large apples than on small ones, yet susceptibility to the disease is determined not so much by size as by the time and nature of the orchard conditions that produce the growth.

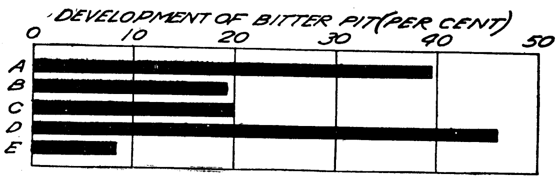

FIGURE 7.—Effects of irrigation on the development of bitter pit in storage on Grimes Golden apples from Wenatchee, Wash. *A*, Heavy irrigation throughout the season; *B*, medium irrigation throughout the season; *C*, light irrigation throughout the season; *D*, medium irrigation followed by heavy; *E*, heavy irrigation followed by light

While bitter pit is largely if not wholly due to orchard conditions, its main development is after removal of the fruit from the tree, in the packing house, in transit, or in storage. It does not spread from one apple to another in the package, but the spots already present may enlarge and others may develop either on fruit already affected or on seemingly sound apples from similar orchard conditions. The development of the disease is delayed by placing it immediately in cold storage, but fruit that shows a tendency to bitter pit at picking time is seldom suited for late keeping.

DROUGHT SPOT

The terms "drought spot," "cork," "punk," "York spot," "fruit pit," "bitter pit," "crinkle," and "Shikkwaluo" (Japanese) have been applied to identical or related troubles, all of which are characterized by malformations in the fruit or the development of large, firm, corky areas in the flesh. (Figs. 8 and 9.) They seem to be due to sudden and severe drought and to be associated with intense heat and often with shallow, open, or otherwise peculiar soils. Badly affected fruit is always discarded at picking time, but apples that are only slightly malformed or have but a small proportion of cork

sometimes get into storage packages. Such fruit seems to have almost as long a storage life as normal apples, but the drought defects always detract from the market value of the fruit.

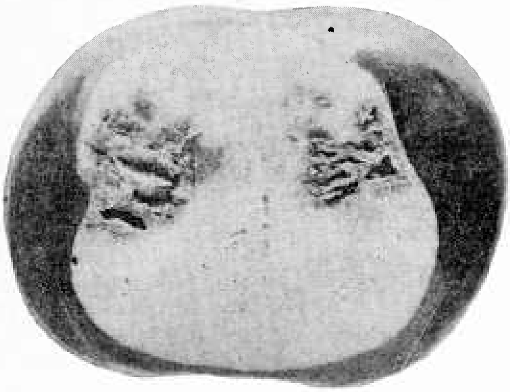

FIGURE 8.—York Imperial apple, showing pockets of cork produced by drought and heat

STIGMONOSE

Stigmonose is a term used to refer to spots and other malformations resulting from insect punctures. In some cases there is a distinct depression on the surface, a considerable layer of hard tissue beneath, and a definite puncture mark, but more often there is merely a brown, corky spot or collection of spots just beneath the skin that bears a close resemblance to bitter pit. (Fig. 10.) The corky tissue, however, is usually firmer and occurs in larger masses than in the case of bitter pit, and the spots are fewer in number and not associated with the conducting tissue or confined to the blossom half of the apple. It is obvious that the control of stigmonose is to be effected by the control of the insects causing the injuries.

Stigmonose has little if any effect upon the storage life of the apples and is to be discriminated against on account of the inferiority of the fruit rather than because of its keeping quality.

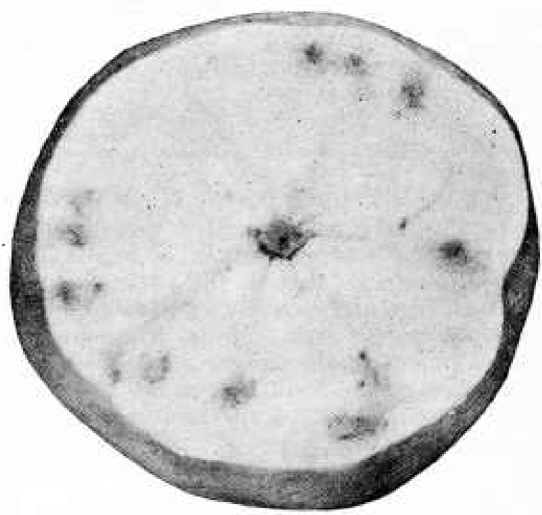

FIGURE 9.—York Imperial apple with a common form of drought spot or cork

WATER CORE

Water core is a nonparasitic disease characterized by a glassy or watery appearance of the flesh. It is somewhat more common in the region of the main vasculars and the core, but may occur in any part of the apple or may involve the whole of it. (Fig. 11.) The affected tissue has a water-soaked apppearance and is usually very hard. Tompkins King, Fall Pippin, Yellow Transparent, Early

Harvest, Rambo, and Winesap are among the more susceptible varieties of apples.

Water core is particularly bad in regions of intense heat and sunlight. High temperature at the time the apples are approaching maturity is especially favorable to the development of the disease. Sunburned apples show a strong tendency to water core. The disease often increases rapidly as the apples become overmature. Water-core apples have a high sap concentration, and the diseased condition is apparently the result of sap exudation under pressure.

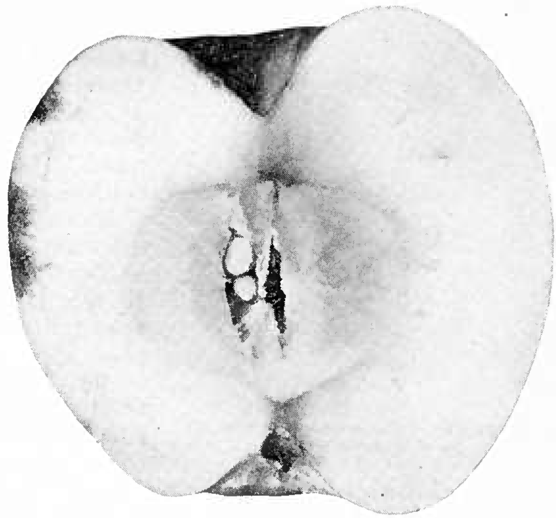

FIGURE 10.—Stigmonose on a Cullen apple

Some persons have thought that the disease may develop in storage, but this conclusion is probably the result of overlooking affected apples at packing time. On the contrary, it has been found that in mild cases of water core the disease may largely disappear in storage. Badly water-cored apples, however, are likely to break down early in storage.

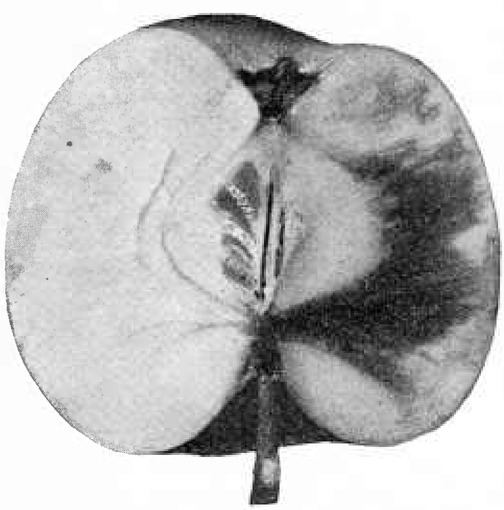

FIGURE 11.—Water core on a Jonathan apple

BITTER ROT

Bitter rot is a disease caused by a parasitic fungus.[4] It is of the greatest importance as an orchard disease and can be controlled by applying Bordeaux mixture as directed in the spray schedules for southern orchards, accompanied in severe cases by the pruning out of cankers. It is a serious disease in sections of Arkansas, Missouri, Virginia, and other Southern States, but is of rare occurrence in northern orchards.

[4] *Glomerella cingulata* (Stonem.) S. and V. S.

The larger rots naturally attract most attention. They are brown or black in color, slightly sunken, with a circular outline and a clear-cut margin. With rots a half inch or more in diameter numerous small black pustules are usually evident beneath the skin or just breaking through it. (Fig. 12.) They are often arranged in a circle and when matured have pink spore masses at their tips. The affected tissue beneath is usually cone shaped. It is softer than that of black rot but much firmer than the rot of blue mold. The tissue adjacent to the rot is often somewhat bitter.

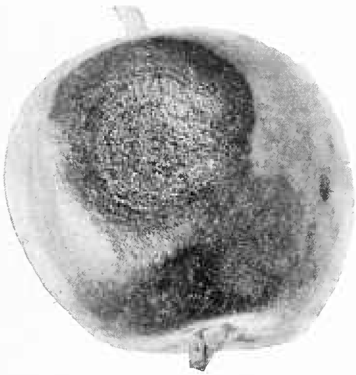

FIGURE 12.—Late stage of bitter rot on a Jonathan apple

Another type of bitter rot, while less common, is of greater importance in storage than the one described above. It is the late infections that appear at picking time as red or purplish spots or specks, with a darker center. (Fig. 13.) They resemble fruit spots, but the center of the spot and the tissue beneath are a solid color instead of being speckled with black or brown. These bitter-rot specks also have an entirely different storage history from fruit spots. Their development has apparently been checked by cool weather before harvest, and in some cases they are incapable of further harm, but as the fruit matures in transit or storage the larger spots may again resume activity. They will make a very active growth at 60° and a very slow development at 50° F., but are entirely inhibited at lower temperatures. After several months in storage at 32° these rot specks will develop rapidly upon removal of the fruit to room temperature.

FIGURE 13.—Bitter-rot spots or specks on a Ben Davis apple. Such spots make no development in cold storage, but may resume growth upon removal

The behavior of bitter rot at different temperatures is shown in Figure 14. It is a hot-weather disease, causing extreme losses in the fall markets and also in delayed shipments and in common storage, sometimes destroying apparently sound fruit from a badly infected orchard within a few days. These losses can be entirely prevented by holding the apples at cold-storage temperatures and can be practically eliminated by cooling to 50° F.

BULL'S-EYE ROT

Bull's-eye rot is the name commonly applied to the rots produced by either northwestern anthracnose[5] or perennial canker.[6] Northwestern anthracnose has been known for a long time as a parasitic orchard and storage disease of apples in the more humid sections of the Pacific Northwest. In recent years a similar but somewhat more virulent and destructive disease has appeared in some of the irrigated sections of Oregon and Washington and has been described as perennial canker. The fruit rots produced by the two organisms are so nearly identical in appearance that it is practically impossible to tell them apart except by microscopical study, and both are included under the name bull's-eye rot.

The rot is light brown in color, and the center of the rot usually is a lighter brown than the margin, giving a zoned or bull's-eyed effect. In later stages the rot may be spotted with pustules which emit creamy spore masses. The surface of the rot is depressed, and the flesh beneath is dry and leathery. The most serious losses from bull's-eye rot occur when the fall rains begin before picking is com-

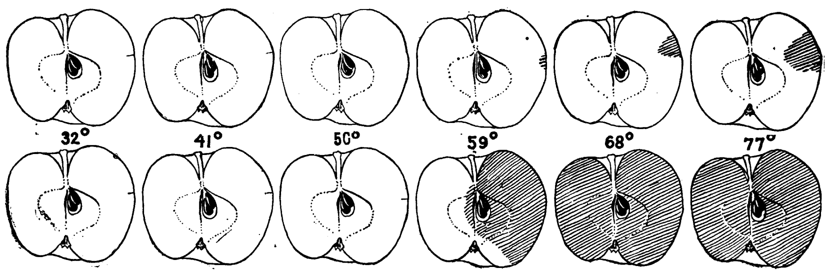

FIGURE 14.—Growth of bitter rot on apples at different temperatures. The upper series shows the size of the rots after two weeks in storage and the lower series after eight weeks in storage, the temperatures ranging from 32° to 77° F. The heavy shading indicates the development of rot

pleted. Apples from trees affected with either anthracnose or perennial canker, although free from rot at picking time, may later become badly diseased in either common or cold storage. In the fall of 1918 apparently sound Salome apples from a tree affected with anthracnose were held in storage at various temperatures. After 7 weeks the apples at 50° F. had an average of 49 rotten spots each, those at 41° had 11 rots to the apple, while those at 32° were still apparently free from rot. At the end of 18 weeks the apples at 32° had developed an average of 6 infraction centers each. The effect of temperature upon the rate of development of anthracnose is shown in more detail in Figure 15. The temperature response of the perennial canker fungus is almost identical with that of the anthracnose.

BLACK ROT

Black rot[7] is a parasitic disease that is of general occurrence on apples of the Atlantic coast and Middle Western States, but

[5] *Neofabraea malicorticis* (Cordley) Jackson.
[6] *Gloeosporium perennans* Zeller and Childs.
[7] *Sphaeropsis malorum* Pk.

seldom if ever occurs in the Rocky Mountain region or the areas to the west. It is worse on summer and fall varieties. The disease can be largely controlled in the orchard by cutting out the limb cankers and following the prescribed spray schedules.

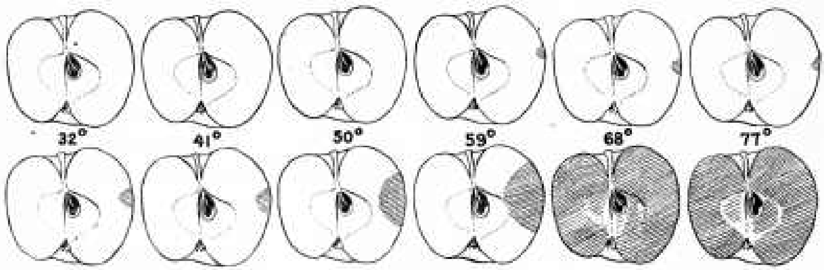

FIGURE 15.—Growth of anthracnose on apples at different temperatures. The upper series shows the size of the rots after two weeks in storage and the lower series after eight weeks in storage, the temperatures ranging from 32° to 77° F. The heavy shading indicates the development of rot

Black rot is one of the darkest colored rots that affect the apple. The diseased areas are usually dark brown or black and often have a decidedly zoned appearance. As the rot enlarges, small black pustules may appear on the surface, but these are not arranged in zones, as is typically the case with bitter rot. As the rot occurs in storage, the zoning is less pronounced and the pustules usually lacking. The affected flesh of black rot is dark brown and quite firm, in striking contrast to the soft light-brown rot produced by blue mold. Black rot usually makes its start at an insect sting or other puncture or at the calyx where injury has resulted from frost or spray, and it sometimes develops as a core rot. (Fig. 16.) It is primarily a rot of ripe fruit, but may often be found as spots one-eighth to one-half of an inch in diameter several weeks before picking time. These develop very slowly and may even appear to be entirely dormant for a time, but later become quite active as the fruit matures.

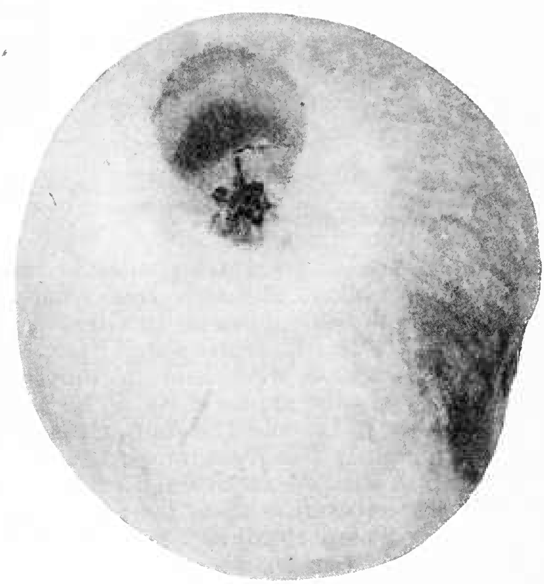

FIGURE 16.—Black rot developing at the calyx on a Ben Davis apple

Black rot continues to grow slowly in cold storage, but it seldom spreads from one apple to another. It makes its development almost

entirely at punctures or bruises or from specklike rots that were overlooked at packing time. Figure 17 shows a Grimes Golden apple affected with Sphaeropsis spots that are too small to seem like rots, yet in a storage test the largest of these spots made a rapid and significant growth. At 68° F. such apples were practically rotted in two weeks, at 59° in four weeks, and at 32° the spots were half an inch in diameter by the end of six weeks.

The temperature relations of black rot are shown in Figure 18.

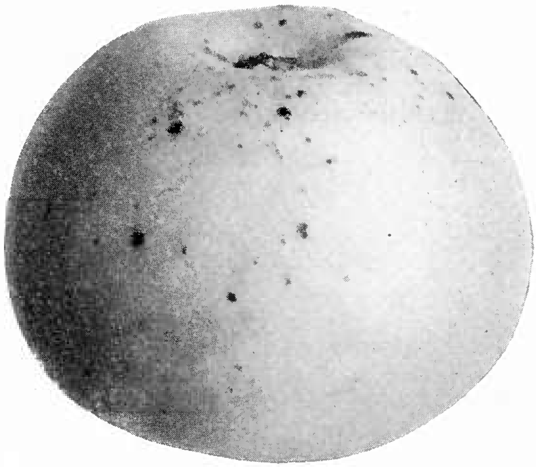

FIGURE 17.—Black-rot spots on a Grimes Golden apple. Such spots may remain dormant for a time but resume growth as the fruit matures

ALTERNARIA ROT

The disease known as Alternaria rot is caused by one or more species of the Alternaria fungus. It is of frequent occurrence on fruit in all sections of the United States and particularly common on apples in the irrigated sections of the West. The Alternaria fungus is the most common cause of core rots, its entrance apparently being favored by the open calyx that frequently characterizes the apples from irrigated orchards. (Fig. 19.) It is the most common cause of the rots that follow Jonathan spot and York skin crack and is also common following scald.

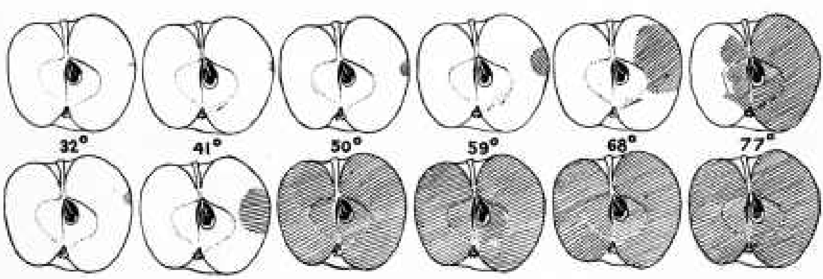

FIGURE 18.—Growth of black rot on apples in storage. The upper series shows the size of the rots after two weeks in storage and the lower series after eight weeks in storage, the temperatures ranging from 32° to 77° F. The heavy shading shows the development of rot

Alternaria rot looks so much like black rot that it is sometimes impossible to distinguish one from the other by growth characteristics. In such cases a distinction can be readily made by resorting to the microscope or to laboratory cultures of the fungus. Alternaria rot, however, is seldom zoned and is often more superficial than black rot, spreading over the surface without extending deep into the tissues.

The development of Alternaria rot is greatly delayed by cold and also by greenness and firmness in the fruit, but it will finally destroy weak and overripe apples at commercial storage temperatures.

BLUE MOLD

Blue mold[8] is a fungous disease confined almost entirely to storage fruit. It is of general occurrence and by far the most destructive of all the storage rots, probably causing 75 per cent of the total rot on stored apples. The affected tissue is quite soft, and the disease is therefore often referred to as soft rot. The rot is light brown in color and has a very characteristic musty odor and taste. When the rot is well advanced, powdery blue-green tufts develop on the surface, giving off countless numbers of spores, each capable of producing a new rot. (Fig. 20.)

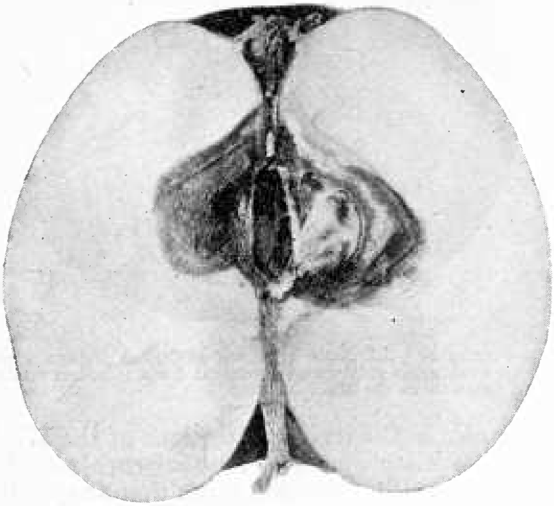

FIGURE 19.—Alternaria core rot on a Stayman Winesap apple

The germ tubes of blue-mold spores are unable to penetrate the sound skin of the apple and must rely upon wounds as points of infection. Stem punctures are one of the most common causes of rot, but finger-nail scratches by the pickers, insect injuries, scab spots, bad bruises, and punctures of any kind may furnish a starting point for the fungus. The disease may spread from one apple to another in storage either by the scattering of the spores or by actual contact of the fruit. When a sound apple is smothered in the remains of a rotten one, the fungus is apparently able to penetrate the skin without the aid of a puncture.

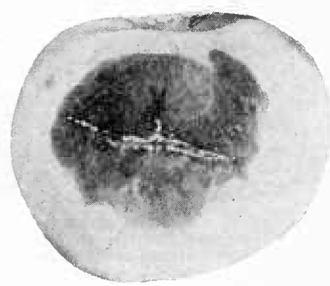

FIGURE 20.—Blue-mold rot on a Yellow Newtown apple

While blue mold is primarily a storage disease, in some of the irrigated sections of the Northwest it sometimes gains entrance at insect stings and rots the apples while still on the tree, but this condition is very exceptional. It is mainly a rot of ripe apples, and overripe fruit is particularly susceptible.

[8] *Penicillium expansum* Link.

Low temperatures greatly delay the development of blue mold, especially on fruit that is not overripe at the time of storage. Cold has a much greater inhibiting effect upon the starting of rots than it has upon their development. Rots that have been allowed to get started while the apples were still warm develop rather rapidly even at cold-storage temperatures. Figure 21 shows the rate of development of blue mold at different temperatures.

The losses from the disease are enormous, but can be largely prevented by careful picking and handling, guarding against finger-nail punctures, basket scratches, barrel bruises, and stem-puncture injury, and by cooling the apples to 32° F. within a day or two after picking. The spread of blue mold in the package is decreased by wrapping the apples, thereby confining the spores and eliminating the direct contact between diseased and sound apples.

PINK ROT

Pink rot[9] is entirely a storage disease. It has sometimes caused heavy storage losses in New York and other Northern States, but

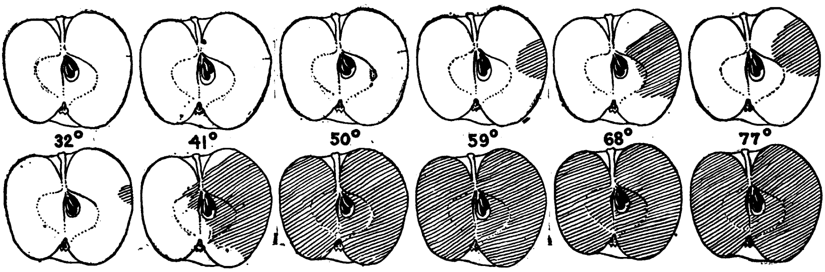

FIGURE 21.—Growth of blue mold on apples in storage. The upper series shows the size of the rots at the end of two weeks after inoculation and the lower series the size at the end of eight weeks, the temperatures ranging from 32° to 77° F. The heavy shading shows the development of rot

is not of economic importance in most fruit sections. The rot is seldom serious except as following scab, beginning its development at the margin of the scab spot. The affected tissue is firm, corky, dry, and has a very bitter taste. In the later stages of the disease the fungus may be found fruiting on the surface, giving the rot a powdery pink appearance that is the basis for the name of the disease. Pink rot grows slowly, especially in cold storage, but may finally destroy the fruit, even at a temperature of 32° F.

SPONGY DRY ROT

Spongy dry rot[10] is a parasitic disease that makes its start in the orchard. It has been reported as causing considerable loss in North Carolina, New York, and other States of the Atlantic coast. It resembles black rot, but the spots are more sunken, the texture of the tissue firmer and drier, and the color more uniformly black throughout. The surface may be roughened by the pustules of fruiting bodies. The rot is apparently unable to penetrate the sound skin. It

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[9] *Cephalothecium roseum* (Fries) Cda.
[10] *Volutella fructi* Stevens and Hall.

is greatly delayed by low temperatures and has never been reported as causing severe losses in cold storage.

BROWN ROT

Brown rot[11] is a parasitic disease of apples in market and storage that occasionally causes considerable loss in the Atlantic coast and Middle Western States and in the humid sections of the Pacific Northwest, the greatest damage usually occurring on the summer and fall varieties. It closely resembles black rot, but may be distinguished from it by its velvety appearance.

FIGURE 22.—Internal breakdown of a Stayman Winesap apple

Brown rot is greatly delayed by low temperatures, yet is less retarded by cold storage than any of the rots previously mentioned.

GRAY MOLD

Gray mold[12] is a parasitic storage disease that often causes serious losses. Its appearance is much like that of blue mold, but it is somewhat firmer and has a distinctly sour taste that is in marked contrast to the musty odor and taste of the former. Its spread from one apple to the other is by contact rather than by a scattering of spores. It is greatly delayed by cold but will finally destroy infected apples even at cold-storage temperatures.

INTERNAL BREAKDOWN

Internal breakdown is a nonparasitic disease associated with large and overripe apples. It occurs on apples from the various fruit sections of the United States and has been reported from Australia under the name of "sleepiness." It occurs on practically all varieties, but is most serious on the summer and early fall apples. It is characterized by a breaking down and browning of the interior of the apple. (Fig. 22.) The riper side of the apple is often more seriously affected than the greener side and the blossom half worse affected than the stem half. During the earlier stages the flesh may be found quite moist, but it later becomes spongy and rather dry and "mealy." The skin usually retains its normal appear-

[11] *Sclerotinia cinerea* (Bon.) Schrot.
[12] *Botrytis* sp.

ance, but is sometimes slightly duller and darker and in the later stages of the disease frequently cracks outward. The presence of the disease can usually be detected by the spongy softness of the apple.

Internal breakdown is particularly common on overmature apples and on those that have been forced late in the season. It may appear at picking time but is largely a storage disease. It is a condition that characterizes the end of the life of the apple, but when it appears prematurely it may be regarded as a definite disease. Delay in the packing house or in transit may be responsible for its appearance later in storage or upon removal. In commercial-storage experiments with Stayman Winesap apples it was found that internal breakdown was greatly decreased by the use of ventilated barrels and by storing in ventilated rooms. The disease is particularly serious in common storage, but fruit with a decided tendency to the disease can not be relied upon for late keeping even in cold storage.

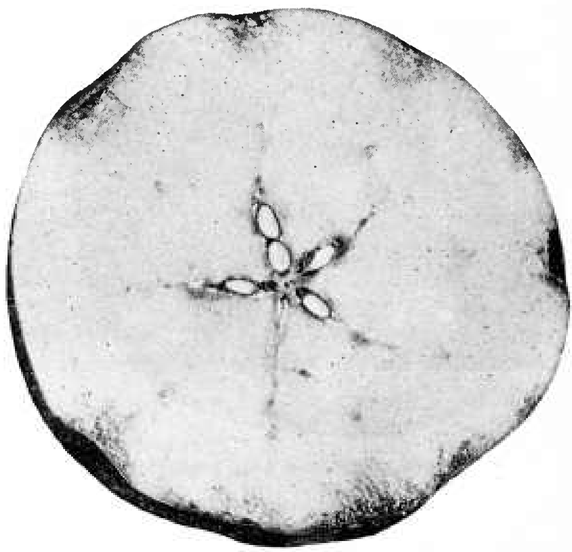

FIGURE 23.—Injury on a Stayman Winesap apple resulting from bruises while frozen

FROST INJURY

The freezing of apples in transit or in storage results in such a variety of effects that it is difficult to give a definite characterization. Frost injury bears a close resemblance to internal breakdown, but the internal browning that results from freezing extends to the surface of the apple, the affected tissue is more watery, and the conducting vessels usually show up prominently as dark-brown strands extending through the flesh. Unlike internal breakdown, frost injury may appear on any part of the apple and on the small green fruit as well as on that which is overripe.

Apples will stand a temperature several degrees below 32° F. without freezing, but reach their limit for cold resistance at about 28° F. Some varieties are touched with frost at this temperature, while others remain free from it. Slightly frozen apples can usually be thawed out in a moist atmosphere without showing injury. Their quality, however, is not as good as before the freezing. Apples are greatly damaged by any bruises made while they are frozen, and if frosted apples are to be saved, great care must be taken in handling the packages. (Fig. 23.) Apples that have been badly frozen or that have had repeated light freezes usually show frost injury, regardless of the methods of thawing.

SOFT SCALD

Soft scald is a nonparasitic disease that is particularly common on the Jonathan and Rome Beauty varieties. In Australia it is known as Jonathan scald. It produces sunken blisterlike effects that extend over the apple in peculiar patterns. (Fig. 24.) Before exposure to the warm air the diseased spots on red fruit surfaces may have a whitish or pink color and the flesh beneath also be pink, the effects apparently being produced by a spread of coloring matter from the skin into the flesh. After exposure to warm air the scalded area and the flesh beneath become light brown in color. The affected tissue is very soft and the line of demarcation between it and the healthy tissue is extremely sharp. The disease resembles certain types of frost injury rather closely, and damages have frequently been paid for frost when the trouble was really soft scald. Frost injury, however, seldom shows the clear-cut margin and the soft, light-brown flesh that characterize soft scald. Secondary fungous infections sometimes follow soft scald, spotting the brown area with black.

FIGURE 24.—Soft scald on a Jonathan apple

Soft scald may be greatly increased by delay in reaching storage, especially if the delay is followed by rapid cooling. It is distinctly a low-temperature disease and is much worse at temperatures that border on the freezing point for apples than at temperatures a few degrees higher. It is usually largely prevented by storing the fruit at 36° to 38° F., or by holding it for 1 or 2 days in an atmosphere containing 20 percent or more of carbon dioxide before storing at 32°.

Soft scald is apparently due primarily to a deficiency in oxygen in the air surrounding the apples. It can be produced by inclosing apples for a few days in an air-tight jar at living-room temperature. In commercial practice the dangers from the disease may be greatly increased by delays in reaching storage, especially if the packages are tight and held without opportunity for ventilation. Under cold-storage conditions soft scald is much more likely to develop at temperatures that border on the freezing point for the apples than at temperatures a few degrees higher.

SCALD

Scald is a transportation and storage disease that is produced by the gases given off by the apples themselves. It is particularly serious on the York Imperial, Grimes Golden, Arkansas (*Mammoth Black Twig*), Rome Beauty, Rhode Island Greening, Stayman Wine-

sap, Wagener, and Baldwin varieties, and it occurs at times on almost every variety of apple.

Scald can be distinguished from all other apple diseases by its preference for the greener side of the apple. In mild cases of the disease the apple is merely tinted with brown (see title-page illustration), but in more severe cases the entire skin layer is killed and sometimes broken down to the extent that it will slough off readily from the flesh. In some instances the flesh becomes dead and brown to a depth of half an inch, and the disease takes on the appearance of an apple rot; but true rot usually spreads down into the flesh in more or less conical shape, while scald is usually diffuse, spreading over a large area without having much depth. An apple that has had its skin killed by scald becomes the ready prey of the various rot organisms, and they soon finish the work of destruction that the scald has begun.

It has been generally believed that scald is due to the warming of the fruit after it has been removed from cold storage. This idea comes from an erroneous interpretation of very familiar facts, and this misconception in regard to the nature of scald has often resulted in throwing the responsibility for its occurrence upon the wrong party. It is true that apples usually show but little scald while held continuously in cold storage, and it is also true that fruit apparently free from disease may become badly scalded after exposure to warm air for a few days; but the apples were already potentially scalded while still in storage and merely required the open air and the higher temperatures to allow their death processes to be completed. Experimental evidence indicates that the real cause of scald is to be found in the accumulation of certain gases given off by the apples themselves.

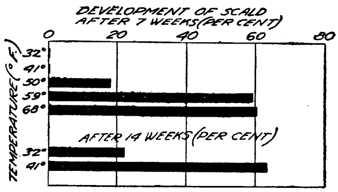

FIGURE 25.—Effect of temperature on the development of scald on Grimes Golden apples. The upper part of the figure shows the percentage of scald at the various temperatures at the end of 7 weeks; the lower part, the percentage of scald at the lower temperatures at the end of 14 weeks. At this time no apples were left at the higher temperatures

The responsibility for scald does not always lie in the same quarter. Its occurrence is influenced by orchard, packing-house, and transportation as well as by storage conditions. Large apples and those that have been forced late in the season by heavy irrigation or rains have an increased susceptibility to scald. Apples that have been scarred and russeted by powdery mildew are rendered more susceptible, while those from trees that have been badly affected with cedar rust are very resistant to scald. Fruit that is picked green is much more susceptible than that which is left on the trees till well matured. The holding of apples in closed packing sheds or in unrefrigerated cars may be responsible for the development of scald later in storage or upon removal from storage. Placing large quantities of warm fruit in a particular storage room instead of distributing it in several rooms is likely to result in delayed cooling and in heavy losses from scald.

The development of scald is much more rapid at high than at low temperatures. (Fig. 25.) Apples scald far less in boxes, crates, or ventilated barrels (barrels with 15 holes three-fourths of an inch by 4 inches cut in the staves) than in the usual commercial barrels, especially if the storage room is allowed considerable change of air.

They scald far less when located near the door of the storage room than when in the back corners away from the aisles. Open stacks and air spaces contribute to the prevention of scald.

The most efficient and practicable method of scald control is that of packing the apples in oiled (not waxed) paper. (Fig. 26.) Oiled wraps should be used on the boxed apples and shredded oiled paper on the apples in barrels, hampers, and baskets. About a half pound of shredded paper is required for each bushel of apples, and it must be well distributed in the package, practically every apple having more or less contact with the paper. The oiled wraps and the shredded oiled paper should carry at least 15 per cent of their finished weight in odorless, tasteless mineral oil (1 pound or more to each 1,600 to 2,000 wrappers), and 18 to 20 per cent of oil or more is desirable, especially with the more susceptible varieties.

INTERNAL BROWNING

Internal browning is a nonparasitic storage disease that is decidedly regional in its occurrence. It has never been reported as of economic importance in the United States except on the apples from the Pajaro Valley in California. The Yellow Newtown is the important storage variety of this section. Internal browning differs from internal breakdown in the fact that the affected tissue is not soft, and also in that the browning first appears as somewhat elongated areas radiating outward from the central portion of the apple and from the primary vascular bundles.

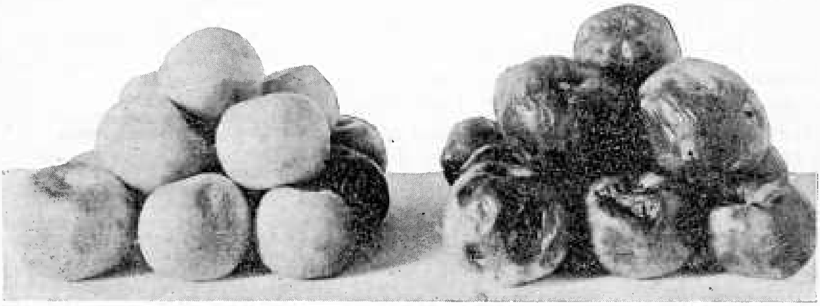

FIGURE 26.—Effect of oiled wrappers in scald prevention. These York Imperial apples were removed from cold storage on March 5 and photographed on March 15. Those on the left were wrapped in oiled wrappers; those on the right were unwrapped. At the time of removal from storage the two lots looked alike, but three days later the unwrapped apples were badly scalded, and at the end of 10 days they were almost entirely rotten, as shown in the illustration. The apples that had been held in oiled wrappers while in storage were still sound after three weeks in a warm laboratory

Internal browning is most effectively controlled by storing the apples at a temperature of 36° to 40° F. The usual cold-storage temperatures are particularly favorable to the development of the disease.

THE STORAGE LIFE OF APPLES

It is generally recognized that each variety of apple has its own storage limitations and that the keeping quality of the fruit varies from year to year. Dealers plan to dispose of their apples while they are still in good condition, and if it is found necessary to hold

them till they are near the end of their storage life a close watch is usually kept to see that their limit is not exceeded. In spite of these precautions large quantities of apples fall prey to rots and scald instead of serving their purpose as food. This loss is not all sustained by the dealer, but may be passed along to the retailer and finally to the consumer. The relation of supply and demand and the behavior of the markets are sometimes responsible for fruit being held too late, but much of the loss on stored fruit is due to misjudgment in regard to its storage life, abuses that destroy its protective skin layer, and faulty shipping and storage conditions.

Fruit spot, stigmonose, and even small blotch specks usually have little effect upon the storage life of the fruit; but scab, black rot, and bitter rot specks may greatly shorten its life. Apples from trees affected by anthracnose or perennial canker and those showing a tendency to bitter pit will probably become diseased even in cold storage. Coarse overgrown apples and apples that are forced late in the season can never be relied upon for late keeping. The sound skin of the apple forms an almost complete protection from storage rots, but punctures and scratches pave the way for early decay. When fruit is placed in cold storage immediately upon picking, the rots develop slowly; but if the rot organisms can have a week's start on the warm fruit they will make a rather rapid growth even at 32° F. Scald is the most deceptive of all the storage troubles. Apples may become badly scalded while in storage, yet appear entirely healthy until exposed to warmer air. This peculiarity of the disease has often resulted in heavy losses and serious misunderstandings in connection with afterstorage shipments of fruit, and it has served as a great handicap in the distribution of apples to smaller centers. The time of the appearance and the severity of scald may be somewhat influenced by the growth conditions in the orchard, but they are largely determined by the treatment that the fruit receives after it has been packed.

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